Musquash Estuary Marine Protected Area Ecosystem Monitoring Plan (2014-2019)

Oceans and Coastal Management Division

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ABSTRACT

The Musquash Estuary Marine Protected Area (MPA) encompasses the largest natural estuary in the Bay of Fundy. The conservation objectives for this MPA focus on protecting the biodiversity, productivity and habitats found in the estuary. The Musquash Estuary MPA Ecosystem Monitoring Plan provides an overview of the twelve indicators that have been selected as the starting point for monitoring the biodiversity, productivity and habitats of the Musquash Estuary, as well as human activities and other pressures that may impact the conservation objectives for the MPA. For each indicator, details including available data sources, collection frequency and priority activities are provided for 2014-2019. Data collected for each of the indicators will be used to evaluate whether the conservation objectives for the MPA are being achieved and this information will be used to inform management for the site. As knowledge of the ecosystem increases, the indicators described here may be further refined to ensure that monitoring activities are as efficient and effective as possible.

RÉSUMÉ

La zone de protection marine (ZPM) de l'estuaire Musquash englobe le plus grand estuaire naturel dans la baie de Fundy. Les objectifs de conservation pour cette ZPM sont axés sur la protection de la biodiversité, de la productivité et des habitats se trouvant dans l'estuaire. Le plan de surveillance écosystémique de la ZPM de l'estuaire Musquash donne un aperçu des douze indicateurs qui ont été choisis comme point de départ pour surveiller la biodiversité, la productivité et les habitats de l'estuaire Musquash, ainsi que les activités humaines et les autres pressions qui peuvent avoir une incidence sur les objectifs de conservation pour la ZPM. Pour chaque indicateur, des détails, y compris les sources de données disponibles, la fréquence de la collecte et les activités prioritaires, sont fournis pour 2014 à 2019. Les données recueillies pour chacun des indicateurs seront utilisées pour évaluer si les objectifs de conservation pour la ZPM sont atteints, et ces renseignements serviront à éclairer la gestion du site. À mesure que les connaissances sur l'écosystème augmentent, les indicateurs décrits dans le présent document peuvent être peaufinés afin de s'assurer que les activités de surveillance sont aussi efficaces et efficientes que possible.

INTRODUCTION

The Musquash Estuary, located approximately 20 km southwest of Saint John, New Brunswick, is the largest undeveloped estuary in the Bay of Fundy. This productive estuary and saltmarsh habitat is home to a wide variety of fish, invertebrates, marine plants, and birds. For a full description of the ecological composition of the estuary see Singh et al. (2000).

The Musquash Estuary Marine Protected Area (MPA) was designated on December 14, 2006 through regulations under Canada's *Oceans Act*. The MPA designation and associated Regulations under the *Oceans Act* apply to the marine environment and associated benthic habitat up to the low water mark in the estuary. In order to support the federal MPA and provide clear jurisdiction over activities in the area, the Government of New Brunswick transferred the administration and control of many of the submerged intertidal provincial Crown lands in the estuary to the Government of Canada through an Order in Council. The transferred intertidal lands, called the Administered Intertidal Area (AIA), are managed by Fisheries and Oceans Canada (DFO) in the same way as the MPA. Therefore any further reference in this document to the MPA includes both the MPA and AIA (see Figure 1 for a map of the MPA and AIA). For more information on the management of the Musquash Estuary MPA, see the Musquash Estuary MPA Management Plan (DFO, 2008).

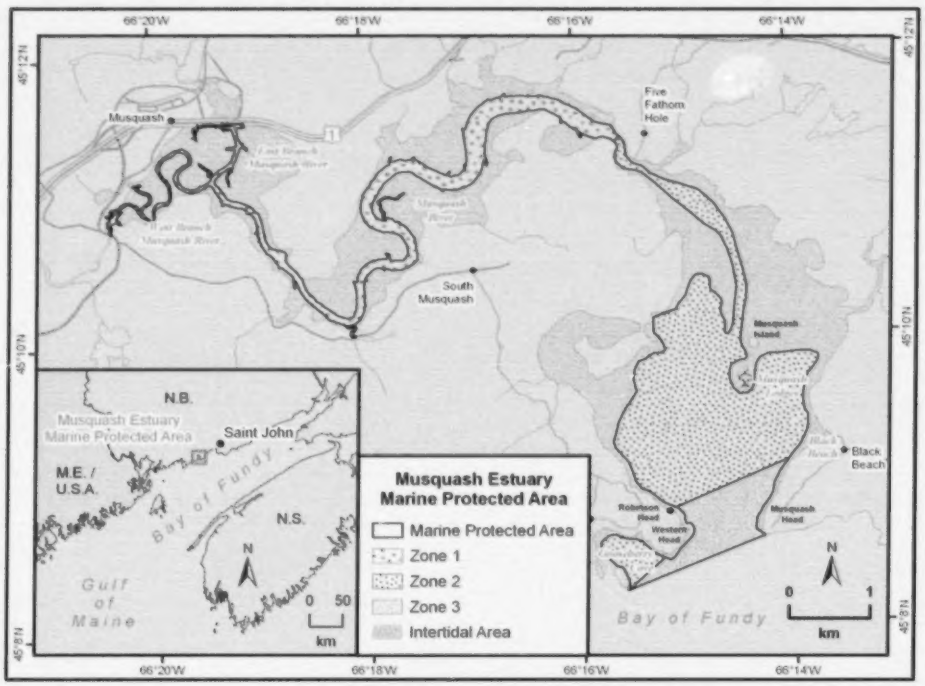

Figure 1. The Musquash Estuary Marine Protected Area (MPA) and Administered Intertidal Area (AIA).

The conservation objectives for the MPA, as outlined in the Musquash Estuary MPA Management Plan (DFO, 2008), are to ensure no unacceptable reduction or human-caused modification in:

A. **Productivity** so that each component (primarily community, population) can play its role in the functioning of the ecosystem by maintaining abundance and health of harvested species;
B. **Biodiversity** by maintaining the diversity of individual species, communities and populations within different ecotypes;
C. **Habitat** in order to safeguard the physical and chemical properties of the ecosystem by maintaining water and sediment quality.

While DFO (Maritimes Region) is responsible for ensuring the objectives described in the Management Plan are met, protection of the Musquash Estuary MPA is achieved collaboratively in cooperation with other regulatory authorities and is guided by the advice of relevant government departments, Aboriginal groups and stakeholders, including members of the Musquash Advisory Committee.

MONITORING AND EVALUATION

Monitoring and evaluation can provide information on whether or not actions are producing the desired outcomes. When applied to MPA management, monitoring is a means of gathering data to be used in the evaluation of MPA effectiveness (i.e., determining the degree to which the goals and objectives of the MPA are being met). Together, monitoring and evaluation are important tools to help managers prioritize activities, highlight successes, identify issues, influence resource allocations and report on progress to the public and other stakeholders (Pomeroy et al., 2005; Hockings et al., 2009).

Several different kinds of monitoring are needed as part of a comprehensive MPA monitoring program (Davies et al., 2011):

- Ecosystem monitoring can be used to determine ecological trends and to identify variations in ecosystem properties that relate to the conservation objectives;
- Activity monitoring can be used to determine the nature and extent of impact from human activities in the area;
- Compliance monitoring can be used to determine whether regulations and legislation around human activities are being followed, and
- Effectiveness monitoring can be used to evaluate the ability of management actions to meet conservation objectives.

Canada has made numerous international and national commitments related to the monitoring and evaluation of MPAs. The following are the key global and domestic commitments:

- Convention on Biological Diversity *Programme of Work on Protected Areas* Goal 4.2 calls for the development and implementation of systems for assessing the management effectiveness of protected areas (Goal 4.2; Convention on Biological Diversity, 2004)
- Canada's *Federal MPA Strategy* highlights the need for evaluation of management effectiveness against goals and objectives as part of program implementation (Government of Canada, 2005)

- *Canada's Ocean Strategy* states that there is a need for accountability frameworks that measure progress, relevance and effectiveness (DFO, 2002)

Monitoring and evaluation can serve a multitude of purposes when it comes to the management of protected areas, but the most prominent one is adaptive management. Adaptive management is a cyclic process of continually improving management policies and practices by learning from the outcomes of previously employed policies and practices (Government of Canada, 2011).

The purpose of this Monitoring Plan is to provide an overview of the indicators selected for ecosystem monitoring and to identify priorities for monitoring in the Musquash Estuary MPA for a five year period (2014-2019). Monitoring activities described in this plan will be conducted as capacity and resources allow.

CURRENT STATE OF MONITORING IN THE MUSQUASH ESTUARY MPA

Research and monitoring efforts in the Musquash Estuary have focused to date on benthic diversity, physical oceanography, sediment profiles, fish community assemblages, bird population surveys, contaminants and other human threats (Cooper et al., 2014). Research and monitoring activities may be conducted by DFO and other partners from government, industry, academia and environmental/community groups.

A suite of 12 ecosystem monitoring indicators (8 ecological indicators and 4 pressures/threats indicators) have been developed through several Canadian Science Advisory Secretariat (CSAS) meetings and reports (Cooper et al., 2011; Cooper et al., 2014; DFO, 2011; DFO, 2013a; DFO, 2013b, DFO, 2013c). These will be used as the starting point for monitoring the Musquash Estuary MPA (and relevant reference locations, where applicable) and for evaluating whether the conservation objectives for the MPA are being achieved. For each of the 12 indicators, monitoring details and status, including a rationale for the indicator, available data sources, collection frequency and priority activities for the next five years have been developed (See Annex 1).

As knowledge of the system increases, there will be opportunities to further refine the indicators to ensure that monitoring activities are as efficient and effective as possible. As part of this on-going adaptive management process, a Musquash Estuary MPA Assessment Framework will be developed and implemented during the life of this plan. This framework will describe how monitoring data will be integrated and analyzed to provide advice on whether the conservation objectives for the MPA are being met. Framework implementation may also help identify indicators that are missing from the monitoring plan and those that are not contributing useful information in terms of MPA effectiveness.

Ecological Indicators

The ecological indicators to be monitored within the Musquash Estuary MPA are summarized in the following table:

Ecological Themes	Indicators
Productivity	1) Total biomass/abundance and spatial distribution of key species in each trophic level o Biomass/abundance of juvenile fish within the estuary o Biomass/abundance of dominant benthic infauna
Biodiversity	2) Number of species per trophic level within each habitat type 3) Number of species at risk within the MPA (by each habitat type if required)
Habitat	4) Total area and location of each habitat type within the estuary, and the proportion and frequency that is disturbed or lost o Total area and location within the estuary of species that provide biogenic structure (e.g. marsh and rockweed) 5) Hydrodynamic and sediment regime within the estuary (e.g., sediment infilling) 6) Temperature and salinity within the estuary 7) Nutrient concentrations within the estuary

Pressures/Threats Indicators

The Regulations for Musquash Estuary MPA place restrictions on the human activities that are allowed within the MPA. Activities that occur within the MPA must be monitored to determine potential environmental impacts and provide information to facilitate adaptive management. The indicators below have been designed to monitor human activities and other pressures that may impact the conservation objectives of the MPA. Data collected for pressures indicators can also be used to monitor aspects of the ecosystem (e.g., catch per unit effort levels for commercial fisheries can be used as a measure of productivity in the MPA).

The following table summarizes the pressures/threats indicators to be monitored within the Musquash Estuary MPA.

Ecological Themes	Indicators
Productivity	8) Commercial and recreational fishing catch per unit effort (CPUE)
Biodiversity	9) By-catch number per impacted species 10) Number of non-indigenous species in the MPA (within each habitat type if required) relative to non-indigenous species in region
Habitat	11) Degree of human induced habitat perturbation or loss 12) Contaminant concentrations within the estuary

Governance Indicators

The governance aspects of the Musquash Estuary MPA are reviewed using a separate suite of 50 indicators designed to address the following 6 categories of management effectiveness: 1) stakeholder interactions, 2) education, stewardship and outreach efforts, 3) research, monitoring, and other permitted activities, 4) management planning, 5) human and financial resource capacity, and 6) surveillance and enforcement. A governance review for the Musquash MPA has been conducted by DFO with input from the Musquash Advisory Committee (DFO, 2015). The findings of this review have been used to inform adaptive management of the site.

REPORTING AND MONITORING PLAN REVIEW

A Musquash Estuary MPA Ecosystem Monitoring Report summarizing ecosystem monitoring activities, data analyses and findings for the MPA will be produced at five year intervals. There may, however, be instances where the results of a specific monitoring activity are especially interesting or show a need for management action. In such situations, those results will be reported at that time. The Musquash Advisory Committee will be a key venue to share and discuss monitoring results. Monitoring reports will be posted online for public distribution.

This Monitoring Plan will be reviewed and revised to incorporate new information about the site as required, or at least every 5 year to coincide with the Musquash Estuary MPA Ecosystem Monitoring Report. Knowledge generated from monitoring efforts may result in changes to indicators, protocols and strategies, and/or may shift the focus (e.g., trophic levels, species or habitats) of monitoring for a given indicator. The next version of the Monitoring Plan will reflect any such changes in support of the adaptive management process.

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ANNEX: MONITORING DETAILS – DATA COLLECTION AND REPORTING FOR ECOLOGICAL INDICATORS

Productivity

INDICATOR 1	Total biomass/abundance and spatial distribution of key species in each trophic level
Indicator Description	Monitoring biomass of key species within each trophic level using standard survey methods. So far, two sub-indicators have been identified: • Biomass/abundance of juvenile fish within the estuary • Biomass/abundance of dominant benthic infauna
Relevant Objective	To ensure no unacceptable reduction or human-caused modification in productivity so that each component (primarily community, population) can play its role in the functioning of the ecosystem by maintaining abundance and health of harvested species.
Rationale	Biomass is a measure of productivity within the ecosystem. Coupling biomass estimates with spatial distribution allows for the identification of highly productive areas for key species within the estuary. By selecting key species at each trophic level, each level can be monitored efficiently. Estuaries provide important habitat for juvenile fish species and monitoring their abundance could aid in the detection of issues related to fish productivity. Likewise, changes in abundance of dominant members of the benthic community may be indicative of changes in the hydrodynamic and sediment regime.
Unit of Measure	Biomass (catch weight per sample effort by species), or abundance (number of individuals per sample effort by species)
Data Source	There have been various fish, bird, plant, and invertebrate sampling efforts and the data to fulfill this indicator will come from a combination of these, and similar future efforts (Cooper et al., 2014; DFO, 2013b; DFO, 2013c).
Data Collection Requirements	To be determined.
Data Collection Contributors	To be determined.
Data Collection Frequency	To be determined.
Triggers for management action	Statistically significant deviation from baseline variability (to be determined).
Priority (2014-2019)	Key species within each trophic level have yet to be identified. A priority for this indicator is to identify key species and develop the protocol for monitoring this indicator. For example, aerial/dive survey data gathered for habitat classification (indicator 4) could be used to characterize distribution and abundance of key marine plant species. For the juvenile fish sub-indicator, preliminary studies exist that characterize abundance of fish species at various locations within the MPA using beach

	seines and fyke nets. The priority for this sub-indicator is to develop and implement a robust sampling protocol and determine the baseline values. For the benthic infauna sub-indicator, data has already been collected as part of annual benthic surveys and could be analyzed to provide measures of abundance.

Biodiversity

INDICATOR 2	Number of species per trophic level within each habitat type
Indicator Description	Monitoring species richness within each trophic level using standard survey methods.
Relevant Objective	To ensure no unacceptable reduction or human-caused modification in biodiversity by maintaining the natural diversity of individual species, communities, and populations within different habitat types.
Rationale	Estimates of species richness provide an indication of biodiversity, and therefore health, of a given ecosystem. Changes in community structure as indicated by measurements of species richness may indicate larger changes/disruptions in the ecosystem.
Unit of Measure	Species richness (e.g., number of species per trophic level for each habitat type)
Data Source	There have been various fish, bird, plant, and invertebrate sampling efforts, and the data to fulfill this indicator will come from a combination of these and similar future efforts (Cooper et al., 2014; DFO, 2013b; DFO, 2013c).
Data Collection Requirements	To be determined.
Data Collection Contributors	To be determined.
Data Collection Frequency	To be determined.
Triggers for management action	Statistically significant deviation from baseline variability (to be determined).
Priority (2014-2019)	Some work to characterize biodiversity within the MPA has been conducted. For example, fish species richness has been quantified at several locations within the MPA using beach seines and fyke nets. As well, benthic infaunal biodiversity estimates (number of taxa per station) have been calculated from samples taken from each of three ecological zones (intertidal, subtidal and channel) within the lower portion of the MPA as part of an on-going benthic survey program. The priority for this indicator is to identify key trophic levels and habitat types to be the focus of monitoring and to develop appropriate monitoring protocols. Efforts will also be made to complete the baseline characterization of fish and benthic species richness at select locations within the MPA.

INDICATOR 3	Number of species at risk within the MPA (by each habitat type if required)

Indicator Description	Monitor use of the MPA by species at risk through standardized surveys. Several at-risk bird species are known to use the Musquash estuary. Of these, at least four are known to breed in the estuary. Several bird surveys are conducted by various groups in and around the MPA (including the Maritimes Marsh Monitoring Program). Some of these surveys are expected to be ongoing.
Relevant Objective	To ensure no unacceptable reduction or human-caused modification in biodiversity by maintaining the diversity of individual species, communities, and populations within different habitat types.
Rationale	At-risk species are important contributors to the biodiversity of the MPA. These species may be especially vulnerable to human pressures.
Unit of Measure	To be determined.
Data Source	Various bird surveys (to be determined for other species if required)
Data Collection Requirements	Following bird survey protocols that align with recovery strategies, action plans and/or management plans for avian species at risk. Monitoring protocols for other species at risk will be developed as needed.
Data Collection Contributors	To be determined.
Data Collection Frequency	To be determined.
Triggers for management action	To be determined.
Priority (2014-2019)	A top priority is to identify how best to incorporate species at risk considerations into MPA monitoring. Specific to bird monitoring, DFO will work with survey coordinators to ensure the MPA is included in existing bird surveys so as to develop a baseline dataset for on-going monitoring. Another priority is to monitor the lists of species identified as either at-risk under the *Species at Risk Act* or depleted as determined by DFO Science. If the geographic distribution of any of these species is presumed to include the MPA, survey protocols can be developed to detect/monitor for the presence of these species.

Habitat

INDICATOR 4	Total area and location of each habitat type within the estuary and the proportion and frequency that is disturbed or lost
Indicator Description	Create and maintain an inventory of the area covered by each habitat type within the MPA including the following sub-indicator: • Total area and location within the estuary of species that provide biogenic structure (e.g., marsh and rockweed) Recently an updated habitat map was created that provides the total area and location of nine distinct habitat types within the Musquash Estuary (Greenlaw et al., 2014).
Relevant Objective	To ensure no unacceptable reduction or human-caused modification in habitat in order to safeguard the physical and chemical properties of the ecosystem by maintaining water and sediment quality.
Rationale	Maintaining an inventory of the habitat types within the MPA is important in monitoring overall ecosystem health and measuring habitat changes over time. Changes in habitat coverage may indicate changes to ecosystem health. Structure providing species/habitats play an important role in estuary ecosystems by providing habitat for the juvenile life stages of many fish and invertebrate species. Knowing the composition of habitat types within the estuary is important for measuring habitat changes over time.
Unit of Measure	Area (km^2) per habitat type; total area and location of species that provide biogenic structure within the MPA
Data Source	Aerial photographs, multibeam, LIDAR, Canadian Hydrographic Service charts, ground surveys, benthic grabs, underwater video surveys
Data Collection Requirements	Following established methods (Greenlaw et al., 2014)
Data Collection Contributors	Fisheries and Oceans Canada
Data Collection Frequency	5 – 10 years
Triggers for management action	Statistically significant deviation from baseline variability (to be determined).
Priority (2014-2019)	A baseline inventory of habitat types within the MPA has been completed using available data (e.g., aerial photos taken in 2007, LIDAR collected during 2006, 2007, and 2008, multibeam collected in 2001, and CHS charts). The current management priority is to gather high resolution photographs from aerial surveys for an updated analysis to be conducted at the end of the period covered by this plan. This will allow for the identification of trends in habitat change/loss. The existing benthic survey program, as well as additional ground and underwater surveys may be used to ground truth data gathered from aerial surveys and may also contribute useful data to better characterize benthic habitat in certain sub-tidal areas.

INDICATOR 5	Hydrodynamic and sediment regime within the estuary (e.g., sediment infilling)
Indicator Description	Characterization of the hydrodynamic regime and sediment deposition/erosion rate through the collection and analysis of sediment samples and water current and freshwater inflow data, and the development and refinement of sediment and hydrodynamic models for the area.
Relevant Objective	To ensure no unacceptable reduction or human-caused modification in habitat in order to safeguard the physical and chemical properties of the ecosystem by maintaining water and sediment quality.
Rationale	Grain size characteristics can help explain the deposition and erosion history of the estuary and how natural or human induced disturbances in sediments can impact the estuary. Characterization of the hydrodynamic regime will help explain the influence of freshwater inputs, tidal flows, and other physical processes (wind, storm surges) on the ecosystem structure and function of the MPA. Changes in the sediment regime within the estuary could be indicative of natural or human induced changes to the estuary environment. Changes in the hydrodynamic regime (e.g., opening and closing the dam) could impact the structure and function of the ecosystem.
Unit of Measure	Sedimentation and erosion rates (e.g., cm/year) based on grain size analysis; freshwater and tidal flow rates (m^3/s) and current speeds (cm/s)
Data Source	Grain size measurements taken from sediment samples within the estuary; hydrodynamic data gathered from current metres, water level data loggers, and flow metres.
Data Collection Requirements	Sediment samples and hydrodynamic data to be collected and analyzed following the protocols and advice developed from previous sampling efforts, as described in Cooper et al., 2014.
Data Collection Contributors	Fisheries and Oceans Canada
Data Collection Frequency	To be determined after baseline is established.
Triggers for management action	Statistically significant deviation from baseline variability (to be determined).
Priority (2014-2019)	A surficial grain size survey is required to analyze the top 0.5 cm of the seabed. Once complete, these data can be used as a baseline to assess seabed change over time. The development of a coupled hydrodynamic – sediment transport model may also be explored to help assess and model the physical drivers of the ecosystem.

INDICATOR 6	Temperature and salinity within the estuary
Indicator Description	Monitoring of physical variables (temperature and salinity) at fixed locations within the estuary. Currently temperature and salinity measurements are only being taken in the estuary in the summer months and opportunistically during research activities. The level of variability from available datasets suggests a need for continued sampling over multiple years to establish a baseline.
Relevant Objective	To ensure no unacceptable reduction or human-caused modification in habitat in order to safeguard the physical and chemical properties of the ecosystem by maintaining water and sediment quality.
Rationale	Changes in physical variables such as temperature and salinity within the estuary can be indicative of larger changes occurring within and outside of the MPA. Estuary species are usually tolerant of periodic changes in temperature and salinity because estuary environments are varied, however, extreme or long-term changes could have negative impacts.
Unit of Measure	Temperature (°C), Salinity (ppt)
Data Source	Measurements taken at fixed locations within the MPA.
Data Collection Requirements	Following established methods.
Data Collection Contributors	Fisheries and Oceans Canada (Saint Andrews Biological Station), Fundy BayKeeper, Eastern Charlotte Waterways
Data Collection Frequency	Seasonal
Triggers for management action	Statistically significant deviation from seasonal baseline variability (to be determined).
Priority (2014-2019)	Conduct seasonal measurements at fixed locations within the MPA to first establish a baseline for these highly variable factors, and then continue to monitor in order to detect changes.

INDICATOR 7	Nutrient concentrations within the estuary
Indicator Description	Monitoring of nutrients (total nitrogen, total phosphorus, Chlorophyll A and dissolved oxygen) at fixed locations within the estuary.
Relevant Objective	To ensure no unacceptable reduction or human-caused modification in habitat in order to safeguard the physical and chemical properties of the ecosystem by maintaining water and sediment quality.
Rationale	Changes in nutrient levels can lead to dangerous algal blooms, which could result in eutrophication.
Unit of Measure	Nutrient levels (nitrogen, mg/L; phosphorus, mg/L; Chlorophyll, A µg/L; dissolved oxygen, mg/L)
Data Source	Nutrient measurements from water samples
Data Collection Requirements	Water samples taken at fixed times of year at fixed stations and analysed for nutrients following established protocols.
Data Collection	Fisheries and Oceans Canada; Eastern Charlotte Waterways

Contributors	
Data Collection Frequency	Annual
Triggers for management action	Statistically significant deviation from baseline variability (to be determined).
Priority (2014-2019)	Conduct seasonal measurements at fixed locations within the MPA to first establish a baseline, and then continue to monitor in order to detect changes.

Pressures / Threats

INDICATOR 8	Commercial and recreational fishing catch per unit effort (CPUE)
Indicator Description	Characterization of catch per unit effort (CPUE) using data for fisheries that occur in and adjacent to the MPA.
Relevant Objective	To ensure no unacceptable reduction or human-caused modification in productivity so that each component (primary, community, population) can play its role in the functioning of the ecosystem by maintaining abundance and health of harvested species.
Rationale	Monitoring catch and effort data on existing fisheries in the MPA will help in describing and tracking fishing-related pressure on the ecosystem.
Unit of Measure	CPUE (e.g., kg of lobster/pot).
Data Source	Logbook data from the Maritimes Fishery Information System (MARFIS) for the scallop fishery. There are currently no appropriate data available for the lobster, elver, eel, clam, and dulse fisheries that may occur within the MPA.
Data Collection Requirements	Fisheries logbook data for the scallop fishery are available via MARFIS. For other fisheries, a Local Ecological Knowledge (LEK) study may be conducted to determine fishing effort in the area based on the protocols of Wagner (2011) and Squires and Gromack (2013). Alternatively, it may be possible to partner with fishers to gather data on fishing activity within the MPA using enhanced logbooks (i.e., reporting forms with fields that provide additional information beyond what is required by licence condition).
Data Collection Contributors	MARFIS data collected and maintained by DFO; possible contributions from industry partners
Data Collection Frequency	Annually for data available via MARFIS or through enhanced logbook reporting. LEK studies may be conducted every 5-10 years.
Triggers for management action	To be determined.
Priority (2014-2019)	Continue to gather and analyse data on fishing activity in the area using available data streams (e.g., MARFIS, LEK, and/or enhanced logbook reporting with industry partners).

INDICATOR 9	By-catch number per impacted species
Indicator	Characterization of by-catch caught within and adjacent to the MPA by

Description	fishery.
Relevant Objective	To ensure no unacceptable reduction or human-caused modification in biodiversity by maintaining the diversity of individual species, communities, and populations within different habitat types.
Rationale	By-catch amount was selected as an indicator in order to monitor the number of non-targeted individuals in each fishery. Monitoring of by-catch levels will help in describing and tracking these fishing-related pressures on the ecosystem.
Unit of Measure	By-catch amount by species (e.g., number of individuals/catch by species)
Data Source	At-Sea Observer Program for the scallop fishery. There are currently no appropriate data sources available for the lobster, elver, eel, clam, and dulse fisheries that may occur within the MPA.
Data Collection Requirements	Data collection for the scallop fishery would follow the established protocols for the At-Sea Observer Program. LEK study protocols may be based on previous work by Wagner (2011) and Squires and Gromack (2013). It may also be possible to gather data in partnership with fishers via enhanced logbooks, as described above.
Data Collection Contributors	At-Sea Observer Program, possible contributions from the Fishermen and Scientists Research Society and the Fundy North Fishermen's Association.
Data Collection Frequency	Annually for data available via MARFIS or through enhanced logbook reporting. LEK studies may be conducted every 5-10 years.
Triggers for management action	To be determined.
Priority (2014-2019)	Continue to gather and analyse data on fishing activity in the area using available data streams (e.g., Observer Program data, LEK, enhanced logbook reporting with industry partners).

INDICATOR 10	Number of non-indigenous species in the MPA (within each habitat type if required) relative to non-indigenous species in region
Indicator Description	Monitor for presence/establishment of non-indigenous species within the MPA using standardized surveys. Monitoring for Aquatic Invasive Species (AIS) has been ongoing in the Bay of Fundy since 2006, and includes a station within the MPA at Five Fathom Hole (Martin et al., 2010). To date no invasive tunicates have been found but European green crab has been reported.
Relevant Objective	To ensure no unacceptable reduction or human-caused modification in biodiversity by maintaining the natural diversity of individual species, communities, and populations within different habitat types.
Rationale	Non-indigenous species have the potential to become invasive species if they become established. Once established, non-indigenous species may compete with native species for space and resources and can impact the natural ecosystem.
Unit of Measure	Number of non-indigenous species; presence/absence of non-indigenous

	species
Data Source	DFO Maritimes AIS monitoring program
Data Collection Requirements	Invasive tunicates will be monitored following the methods outlined in Martin et al. (2010) as well as opportunistic sampling and monitoring for other invasive species. While green crab monitoring protocols exist, a Musquash-specific sampling regime is under development.
Data Collection Contributors	Fisheries and Oceans Canada
Data Collection Frequency	Annual
Triggers for management action	Statistically significant deviation from baseline variability (to be determined).
Priority (2014-2019)	Continue to monitor for invasive tunicates at Five Fathom Hole as part of DFO's AIS monitoring program for the Bay of Fundy. As preliminary trapping efforts have identified green crab within the MPA, a priority will be to design and implement a green crab monitoring project at selected locations within the MPA. Monitoring data will be used to inform a risk assessment to determine if there is a need for dedicated efforts to manage the green crab population within the MPA.

INDICATOR 11	Degree of human induced habitat perturbation or loss
Indicator Description	Monitoring habitat changes through time using aerial and ground survey data, and direct pressure monitoring using marine debris surveys.
Relevant Objective	To ensure no unacceptable reduction or human-caused modification in habitat in order to safeguard the physical and chemical properties of the ecosystem by maintaining water and sediment quality.
Rationale	Estuarine environments are sensitive to anthropogenic habitat disturbance. Through monitoring, human-induced habitat impacts (such as from coastal construction and/or dumping) can be detected and addressed.
Unit of Measure	To be determined. For example, percent change in area (by habitat type) may be used to track habitat loss over time. For the marine debris surveys, number of items per category (e.g., plastics, metal, glass, rubber, etc.).
Data Source	Aerial surveys (including from drone surveys), shoreline surveys, annual photographs at selected stations.
Data Collection Requirements	Following established methods.
Data Collection Contributors	Fisheries and Oceans Canada (arranges for aerial surveys); the Conservation Council of New Brunswick/Fundy Baykeeper conducts marine debris surveys at two locations within the MPA and takes annual photographs at selected locations.
Data Collection Frequency	The Fundy BayKeeper marine debris surveys occur monthly during summer and fall. Annual photographs are also taken of specific areas that may be impacted by human disturbance. Aerial photographic surveys should be

	conducted every 5 – 10 years.
Triggers for management action	Significant disturbance that could lead to changes in the estuarine environment (to be determined).
Priority (2014-2019)	Aerial survey data will be acquired and analyzed during the period covered by this plan, and marine debris surveys will continue to be conducted during the summer months.

INDICATOR 12	Contaminant concentrations within the estuary
Indicator Description	Monitoring of contaminants (metals, semi-volatile organics such as polyaromatic hydrocarbons, faecal coliform bacteria) at fixed stations including known/potential points of entry within the MPA. Biological monitoring using appropriate indicator species may inform this indicator.
Relevant Objective	To ensure no unacceptable reduction or human-caused modification in habitat in order to safeguard the physical and chemical properties of the ecosystem by maintaining water and sediment quality.
Rationale	Contaminants have the potential to impact species and habitats within the MPA and levels of contamination can provide insight into the overall ecosystem health in the estuary.
Unit of Measure	For metals and semi-volatile organics: parts per million, mg/kg, etc. For faecal coliforms: number of colony forming units (CFUs) per 100 ml
Data Source	Sediment (metals, semi-volatile organics) and water samples (faecal coliforms) collected within the MPA.
Data Collection Requirements	Following established methods.
Data Collection Contributors	Fisheries and Oceans Canada (contaminants); Eastern Charlotte Waterways (faecal coliforms)
Data Collection Frequency	As needed for metals and semi-volatile organics; seasonal for faecal coliforms
Triggers for management action	Increase in contaminant levels above background levels according to the Canadian Council of Ministers of the Environment's Environmental Quality guidelines.
Priority (2014-2019)	Continue to monitor for potential heavy metals (e.g., vanadium and nickel) contamination from the Coleson Cove Power Plant landfill point source at selected locations within the MPA. Begin monitoring regime to assess baseline levels of faecal coliform bacteria at fixed locations within the estuary. Explore other options for contaminants monitoring, including biological monitoring using sentinel species, such as Atlantic silversides (Doyle et al., 2011) or lobster (Chou et al., 2004).